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F1V VCAA V106 V111 V416 V420
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GB 1357713 A

(58) Field of Search
UK CL (Edition H) F1V
INT CL^4 F01D

(54) Cooling of turbine blades of a gas turbine engine

(57) An unshrouded turbine blade (38) comprises an aerofoil portion (44) with a tip (54), remote from the root (40) and closed by a tip cap (66). A suction side wall (46) of the aerofoil portion (44) has a portion (56) which extends radially beyond the tip (54) to form a cooling passage (74) with an L-shaped arm (76) which extends radially from the tip cap (66) and transversely from the leading edge (50) to the trailing edge (52) of the aerofoil. An aperture (80) at the leading edge of the tip cap allows cooling air to be supplied into the cooling passage; and the flow of cooling air from the leading edge to the trailing edge of the cooling passage provides controlled cooling of the portion (56) and tip (54) of the aerofoil.

Fig.3.

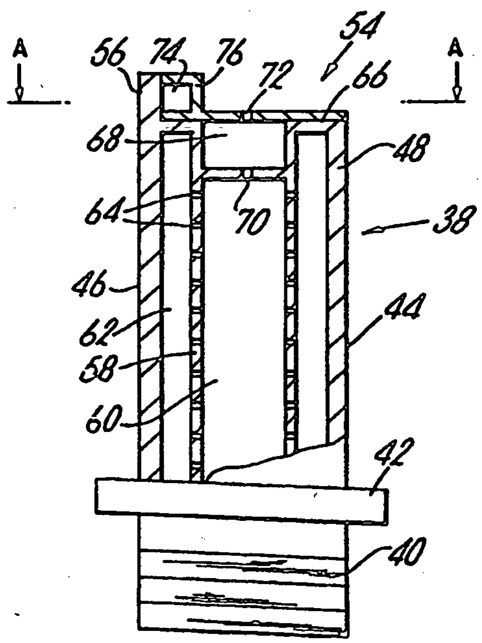
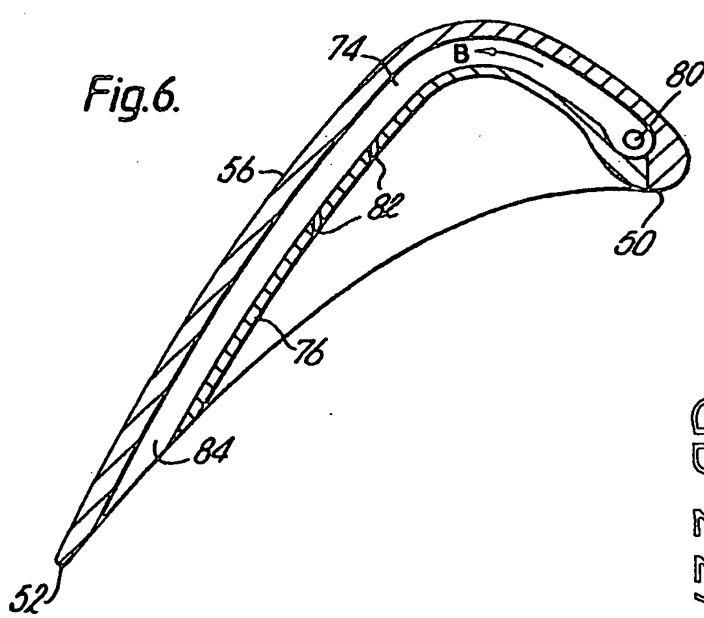


Fig.6.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1.

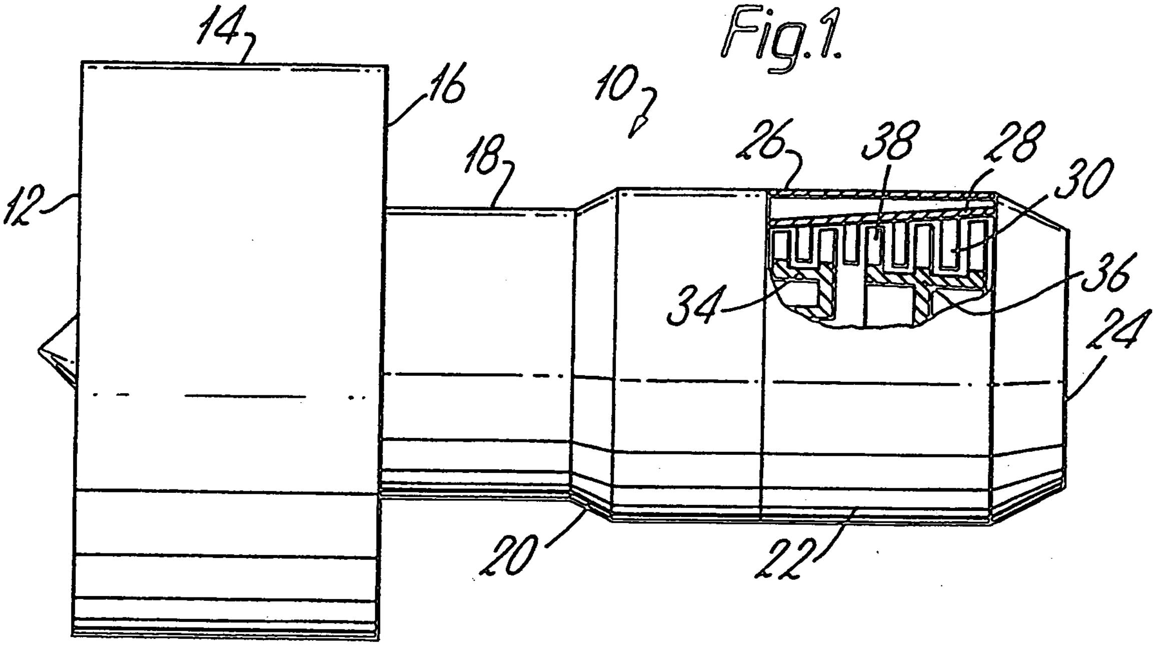


Fig.2.

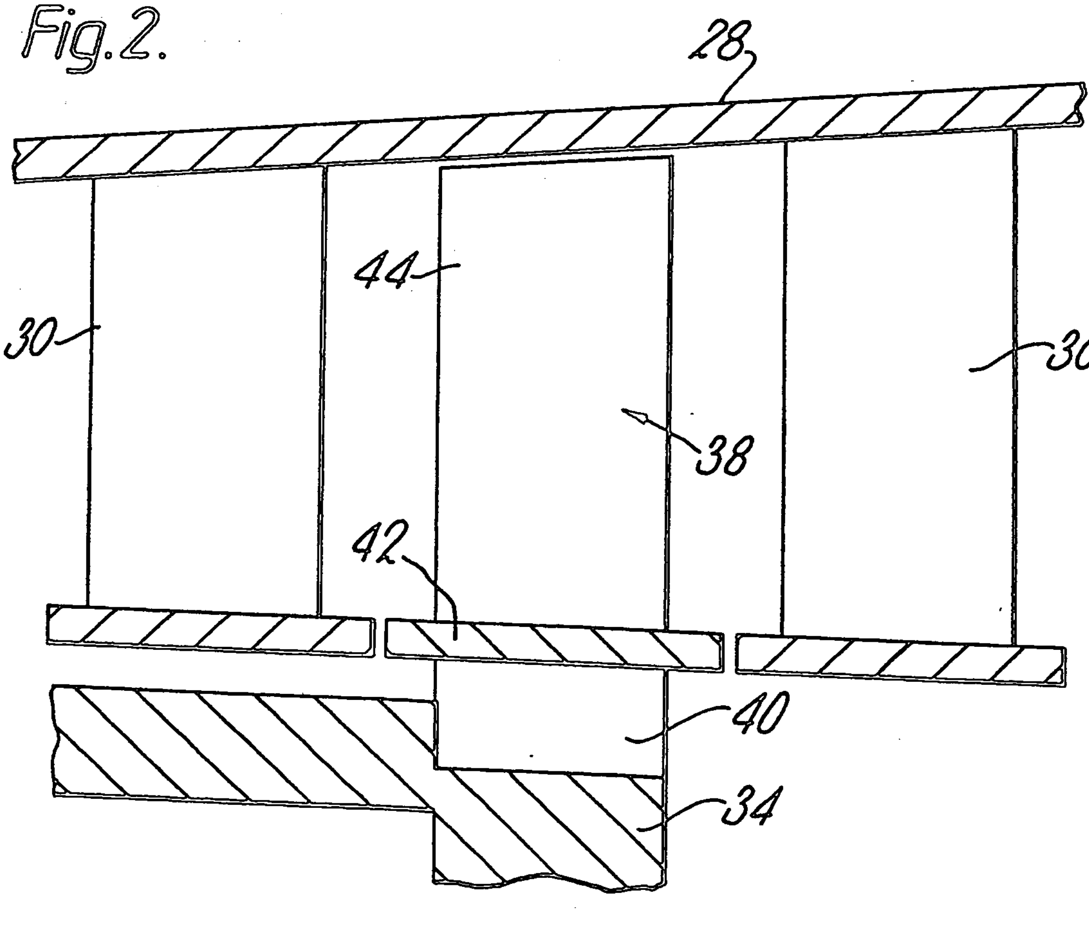


Fig.3.

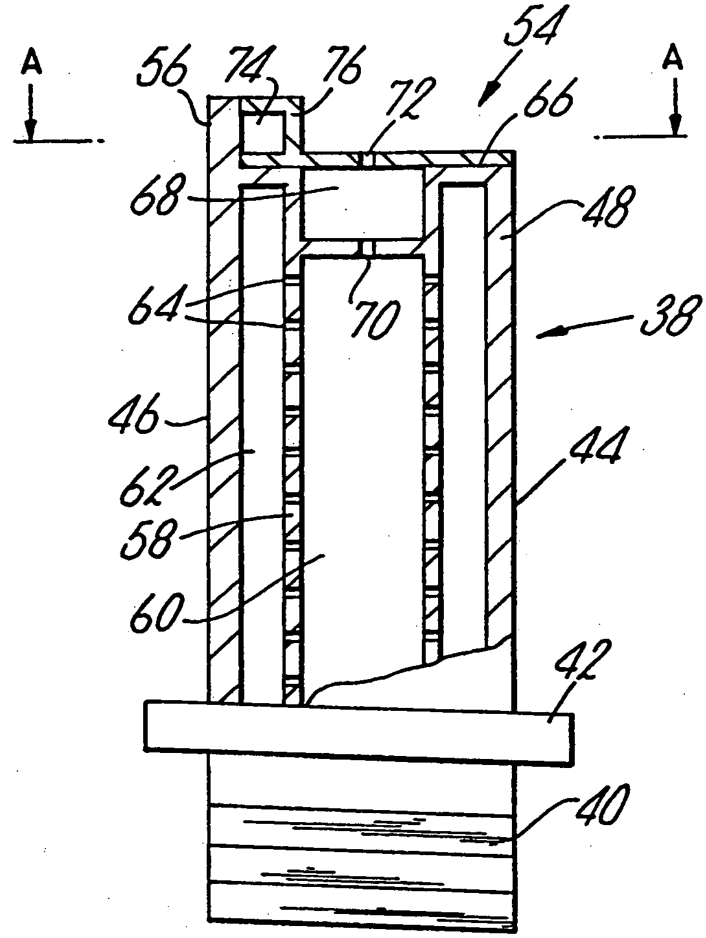


Fig.4.

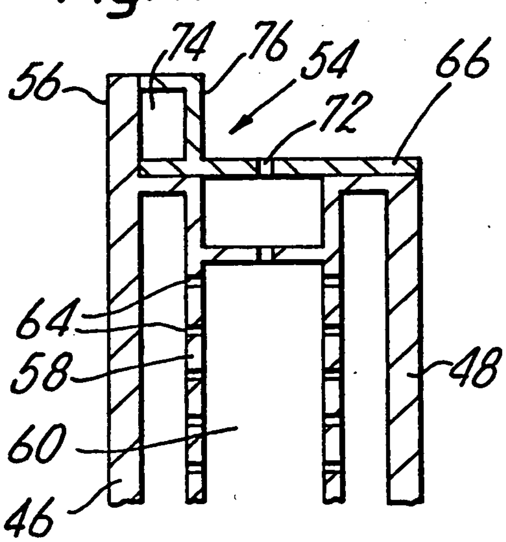


Fig.5.

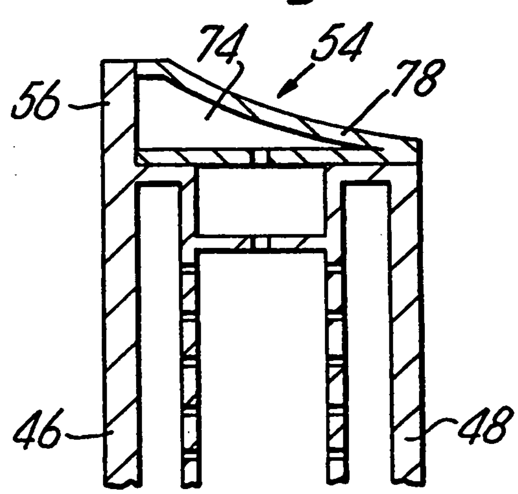


Fig.6.

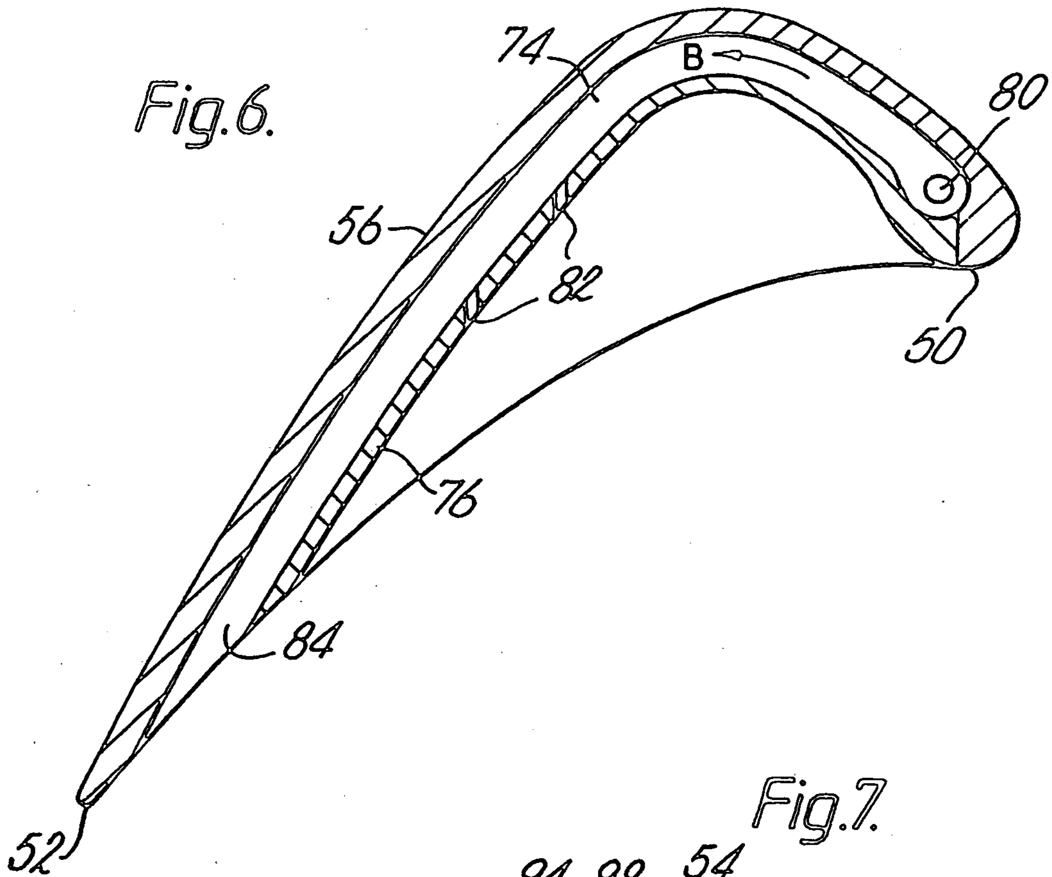


Fig.7.

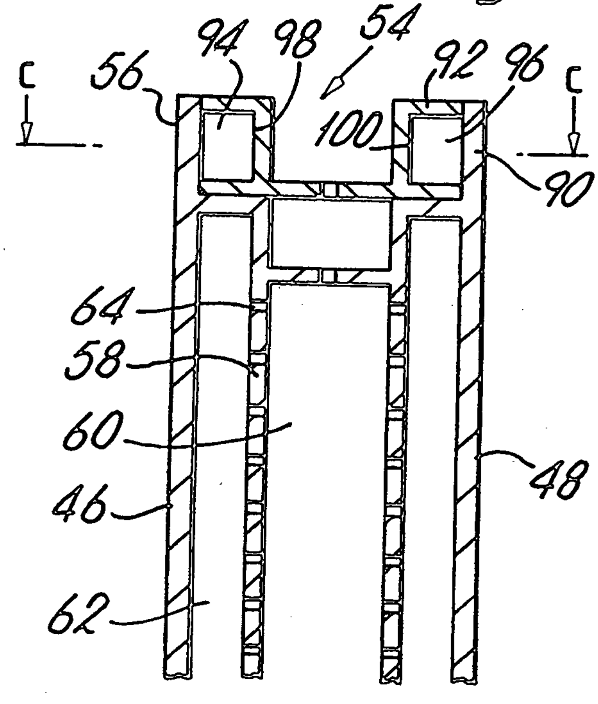
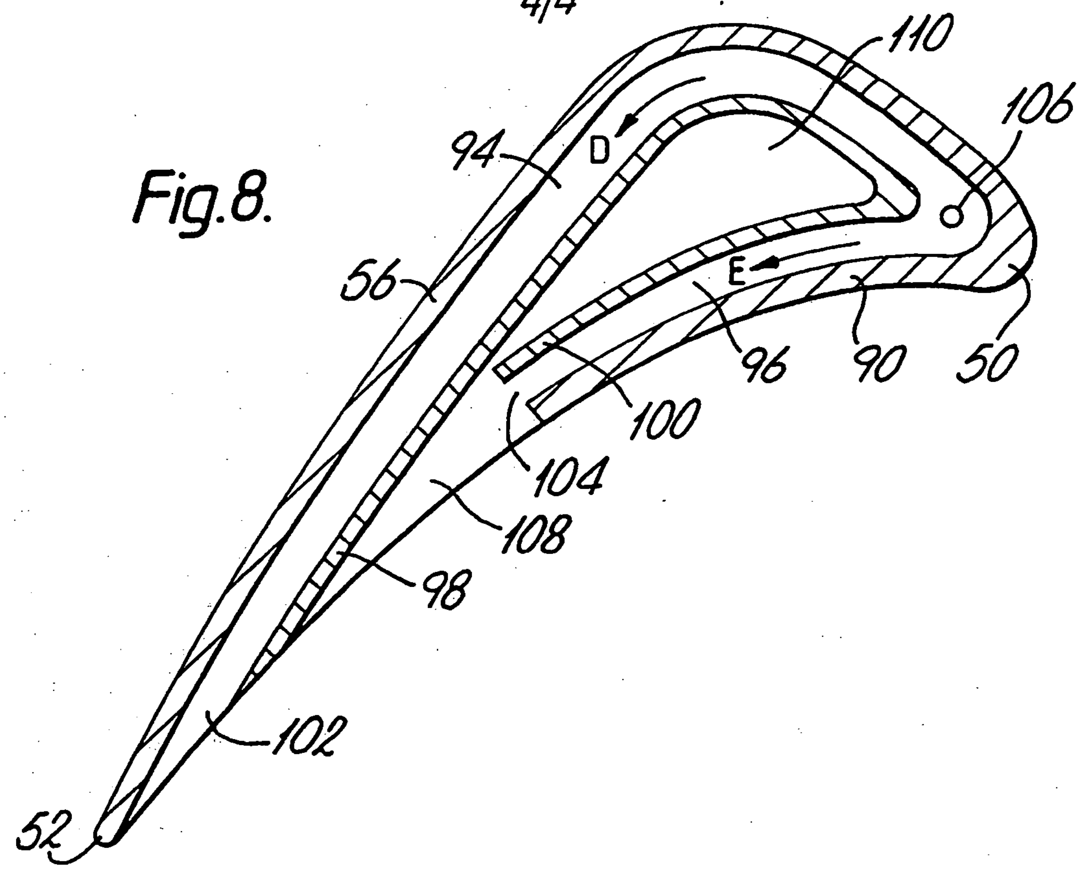


Fig.8.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E
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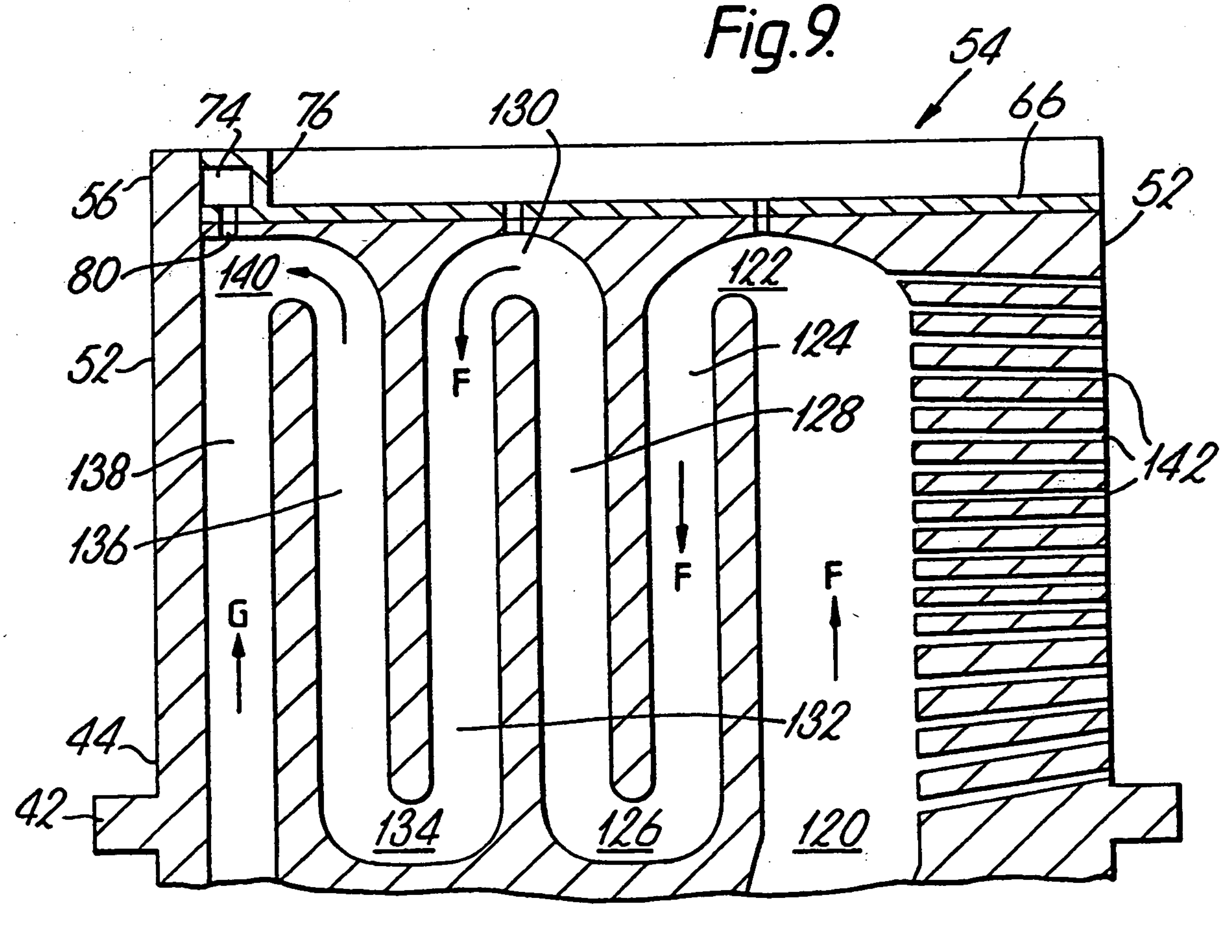
52

Fig.9.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COOLING OF TURBINE BLADES FOR A GAS TURBINE ENGINE

The present invention relates to cooling of turbine blades for gas turbine engines, and is particularly concerned with unshrouded turbine blades.

The desire to increase the efficiency of the turbine section of a gas turbine engine has resulted in increases in the operational speed of rotation of the turbines. This causes increases in the centrifugal forces acting on the blades and reduces their creep life. This has made it desireable to use unshrouded turbine blades in order to reduce the centrifugal loading acting on the turbine blades and to increase the creep life.

However, with the shroud removed the clearance between the tip of the turbine blade and the surrounding stator shroud must be reduced as much as possible to prevent overtip leakage and a consequent loss of turbine preformance. With a small clearance between the tip of the turbine blade and the turbine inner casing there is always a danger of rubbing with the inner casing. The conventional method of reducing damage from rubbing is to have thin walls extending radially from the blade tips.

The use of thin walls extending radially from the tip of the turbine blade has a major problem in that the thin walls are difficult to cool in order to prevent burning. This problem will be compounded by a future need to increase the temperature of operation of the turbine.

Existing methods of cooling the thin walls at the turbine blades tip uses a row or rows of film cooling holes in the turbine blade which are positioned as near the tip as possible but which are unsuitable, as the cooling air is taken through the tip clearance. A further method has been to use radially extending passages in the walls, which eject cooling air into the tip clearance, these may become blocked due to rubbing with the inner casing.

The present invention seeks to provide an unshrouded turbine blade which has improved cooling of the walls at the tip of the turbine blade.

Accordingly the present invention provides an unshrouded turbine blade suitable for use in a gas turbine engine comprising a root portion, a platform portion, and an aerofoil portion, the root portion and platform portion having internal passages adapted to supply cooling air into the aerofoil portion, the aerofoil portion having a leading edge and a trailing edge and being defined by a pressure surface wall and a suction surface wall, the aerofoil portion having internal passages adapted for the flow of cooling air therethrough in order to provide cooling of the aerofoil portion, the aerofoil portion having a closed tip at an end remote from the platform portion, the closed tip of the aerofoil portion having a cooling passage extending transversely from the leading edge to the trailing edge of the aerofoil portion along the suction surface wall, the cooling passage being formed at least partially by a portion of the suction surface wall extending outwardly from the closed tip, the closed tip having a feed aperture at the leading edge of the aerofoil portion adapted to supply cooling air from the internal passages of the aerofoil portion into the cooling passage, the cooling air supplied to the cooling passage flows from the leading edge to the trailing edge to provide controlled cooling of the portion of the suction surface wall and the closed tip of the aerofoil, the cooling air being discharged from the trailing edge of the aerofoil portion.

The closed tip of the aerofoil portion may have a second cooling passage extending transversely from the leading edge towards the trailing edge of the aerofoil portion along the pressure surface wall, the second cooling passage being formed at least partially by a portion of the pressure surface wall extending outwardly from the closed tip, the feed aperture supplying cooling air into the cooling passage and the second cooling passage.

The portion of the pressure surface wall and the second cooling passage may be spaced from the trailing edge of the aerofoil portion.

The tip of the aerofoil portion may be closed by a tip cap, the tip cap forming the cooling passage in cooperation with the portion of the suction surface wall.

The tip cap may have an outwardly extending L-shaped arm which extends from the leading edge to the trailing edge of the aerofoil portion to form the cooling passage.

The outwardly extending L-shaped arm may have a plurality of apertures to discharge cooling air onto the pressure surface of the arm to cool hot spots.

The tip cap may be aerodynamically shaped.

The tip of the aerofoil portion may be closed by a tip cap, the tip cap forming the cooling passage in cooperation with the portion of the suction surface wall and forming the second cooling passage in cooperation with the portion of the pressure surface wall.

The tip cap may have a first outwardly extending L-shaped arm which extends from the leading edge to the trailing edge of the aerofoil portion at the suction side of the tip cap to form the cooling passage, the tip cap having a second outwardly extending L-shaped arm which extends from the leading edge towards but spaced from the trailing edge of the aerofoil portion at the pressure side of the tip cap to form the second cooling passage.

The internal passages of the aerofoil portion may be formed by the pressure and suction side walls and an impingement tube spaced therefrom, the impingement tube supplying cooling air to impinge upon and convectively cool the pressure and suction side walls.

The internal passages of the aerofoil portion may form a forward flowing multipass cooling system in which the cooling air is supplied to the tip cooling passages or passages.

The present invention will be more fully described by way of reference to the accompanying drawings in which:-

Figure 1 is a cut away view of a gas turbine engine showing the turbine section and an unshrouded turbine blade according to the present invention.

Figure 2 is an enlarged view of part of the turbine section showing an unshrouded turbine blade.

Figure 3 is a sectional view to an enlarged scale through an unshrouded turbine blade according to the present invention.

Figure 4 is a sectional view to an enlarged scale through a second embodiment of an unshrouded turbine blade according to the present invention.

Figure 5 is a sectional view to an enlarged scale through a third embodiment of an unshrouded turbine blade according to the present invention.

Figure 6 is a sectional view in the direction of Arrows A in figure 3.

Figure 7 is a sectional view to an enlarged scale through a fourth embodiment of an unshrouded turbine blade according to the present invention.

and figure 8 is a sectional view in the direction of Arrows C in figure 7.

Figure 1 shows a by-pass gas turbine engine 10, which comprises in flow series an inlet 12, a fan 14, a fan outlet 16, a compressor 18, a combustion system 20, a turbine section 22 and an exhaust nozzle 24. The operation of the gas turbine engine is conventional and will not be discussed herein. The turbine section 22 of the gas turbine engine 10, comprises an outer casing 26, and an inner casing 28 which forms the outer boundary of the flow path through the turbine section 22. The inner casing 28 carries a number of stages of circumferentially arranged stator vanes 30 which are arranged axially alternately with stages of circumferentially arranged unshrouded turbine blades 38 which are carried on rotors 34 and 36.

The stator vanes 30 and rotor blades 38 are shown more clearly in figure 2. The stator vanes 30 extend radially inwards from the inner casing 28 and are spaced radially from the circumference of the rotors 34 and 36. The turbine blades 38 extend radially outwards from the rotors 34 and 36 and are spaced radially from the inner surface of the inner casing 28 by a small tip clearance. THe turbine blades 38 comprise a root portion 40, by which the turbine blade 38 is secured to the rotor 34, 36 a platform portion 42 and an aerofoil portion 44.

The aerofoil portion 44 of the turbine blade 38 is shown in figures 3 and 6 and is defined by a suction side wall 46 and a pressure side wall 48 which extend from the leading edge 50 to the trailing edge 52 of the aerofoil portion 44. The radial extremity of the aerofoil portion 44 remote from the root 40 has a tip 54 which forms a small clearance with the cooperating inner surface of the inner casing 28, and a portion 56 of the suction side wall 46 extends outwardly, generally radially, beyond the tip 54. The aerofoil portion 44 is hollow and an impingement tube 58 is positioned within the aerofoil portion 44 and is spaced from the suction and pressure side walls 46 and 48 to form chamber 62 which is interconnected by apertures 64 in the impingement tube 58 to a chamber 60 formed within the impingement tube 58. The tip 54 of the aerofoil portion 44 is closed by a tip cap 66 which is formed by casting and is then brazed to the tip 54. The tip cap 66 closes and forms a chamber 68 with the aerofoil portion 44, and apertures 70 in the impingement tube 58 and apertures 72 in the tip cap 66 allow the passage of cooling air to the tip of the blade. The chamber 68 may also be provided with tip dampers, not shown. The tip cap 66 has an L-shaped arm 76 which extends radially from the tip cap and extends transversely from the leading edge 50 to the trailing edge 52 along the suction side of the aerofoil portion 44 to form a closed cooling passage 74, with the suction wall portion 56. The tip cap 66 is provided with an aperture 80 at the leading edge in order to supply cooling air from chamber 62 in the aerofoil portion into the cooling passage 74, and the cooling

passage 74 has an exit 84 at the trailing edge of the aerofoil portion. The L-shaped arm 76 may be provided with apertures 82 to direct cooling air from the cooling passage towards the pressure side in order to cool hot spots.

In operation cooling air from the compressor of the gas turbine engine is supplied to the turbine section for cooling purposes. A portion of this cooling air is used to cool the turbine blades. The cooling air is supplied through internal passages in the root portion 40 and platform 42 to the chamber 60 formed within the impingement tube 58. The cooling air is then supplied through the apertures 64 into chamber 62 formed between the impingement tube 58 and the suction and pressure side walls 46 and 48 to provide impingement and convective cooling of the side walls. The cooling air can then be discharged from the aerofoil portion through apertures in the pressure and suction walls to give film cooling of the aerofoil portion over the suction and pressure side walls and at the trailing edge, as is well known in the art. A portion of the cooling air is supplied from chamber 62 through the aperture 80 at the leading edge of the tip cap 66 into the cooling passage 74, and this cooling air flows in the direction of arrow B following and convectively cooling the portion 56 of the suction side wall 46 as it flows to the trailing edge 52 and outlet 84. The L-shaped arm 76 of the tip cap 66 is also convectively cooled by the cooling air passing along cooling passage 74, and a portion of the cooling air may be discharged from the apertures 82 to cool local hot spots in the vicinity of the blade tip 54 on the pressure side of the arm 76.

This arrangement provides good controlled cooling of the tip of the unshrouded turbine blade, and in addition the increase in thickness of the suction side wall by the use of the arm of the tip cap to form the cooling passage is not sufficiently large to produce major damage from rubbing with the inner casing. Also this arrangement does not have a portion of the pressure side wall extending beyond the closed tip, this prevents burning of the pressure side wall

as this is the main area for burning of conventional unshrouded turbine blades, and reduces area for rubbing.

The embodiment in Figure 4 is identical to that in Figure 3, but the height of the portion 56 is increased and L-shaped arm 76 is increased accordingly.

Figure 5 shows another embodiment which is similar to those in Figures 3 - 4 but has a tip cap 78 which is aerodynamically shaped.

The embodiment in Figures 7 and 8 is similar to the embodiment in Figures 3 to 6 in that the aerofoil portion has an impingement tube, and a portion 56 of the suction surface wall 46 extending radially beyond the tip 54. The aerofoil portion 44 also has a portion 90 of the pressure surface wall 48 extending radially beyond the tip 54, the portion 90 extends from the leading edge 50 towards, but is spaced from, the trailing edge 52. A tip cap 92 closes the tip of the aerofoil portion 44, and the tip cap has L-shaped arms 98 and 100 which form a closed first cooling passage 94 and a closed second cooling passage 96 with the suction surface wall portion 56 and the pressure surface wall portion 90 respectively. The tip cap 92 has an aperture 106 at its leading edge in order to supply cooling air from the aerofoil portion into the cooling passages 94 and 96, and the cooling passages 94, 96 have exits 102 and 104 at the trailing edge of the wall portions 56 and 90.

A recess 110 is formed at the blade tip between the L-shaped arms 98 and 100 of the tip cap 92, and a cut away portion 108 is formed on the pressure surface of the turbine blade between the trailing edge of the first L-shaped arm 98 and the trailing edges of the second L-shaped arm 100 and wall portion 90.

In operation cooling air from the compressor cools the turbine blade as in the embodiments of figures 3 to 6, but the portion of cooling air supplied from chamber 62 through the aperture 106 is supplied into both the first and second cooling passages 94, 96, and the cooling air flows in the directions of arrows D and E respectively following and convectively cooling the wall portions 56

and 90 of the suction and pressure side walls 46 and 48. The L-shaped arms 98 and 100 of the tip cap 92 are also cooled by the cooling air in the cooling passages as it flows to the outlets 102 and 104.

This arrangement overcomes a loss of tip lift in the embodiment in figures 3 to 6 at the leading edge of the aerofoil by providing the wall portion 90 extending beyond the tip, together with the arm 100. The wall portion 90 does not extend all the way to the trailing edge of the aerofoil to maintain a smaller area for rubbing.

The cooling aperture sizes, cooling air pressure are designed to prevent starving of the leading edge of the aerofoil due to the cooling passages. The aerofoil portion could be provided with a separate passage to supply the cooling passages in the tip to prevent starving of the . leading edge of the aerofoil.

Figure 9 shows a further embodiment in which the aerofoil portion 44 of the turbine blade is provided with a forward flowing multipass cooling system. Cooling air flows radially along internal passage 120 at the trailing edge 52 of the turbine blade, until it is turned through 180° at a turning passage 122. In a similar fashion the cooling air flows along internal passages 124, 128, 132 and 136 being turned at turning passages 126 and 130 and 134 in the direction of arrows F.

Cooling air is also supplied along internal passage 138 in direction of arrow G at the leading edge 50 of the aerofoil to chamber 140 and with cooling air from passage 136, is supplied through aperture 80 into the cooling passage 74.

The internal passage 120 is also provided with a number of trailing edge passages 142 to provide film cooling of the trailing edge of the aerofoil.

It may of course, be possible to form the cooling passages completely within the wall portions extending from the tip of the aerofoil portion, and the L-shaped arms on the tip caps would not then be required.

Claims:-

1. An unshrouded turbine blade suitable for use in a gas turbine engine comprising a root portion, a platform portion and an aerofoil portion, the root portion and platform portion having internal passages adapted to supply cooling air into the aerofoil portion, the aerofoil portion having a leading edge and a trailing edge and being defined by a pressure surface wall and a suction surface wall, the aerofoil portion having internal passages adapted for the flow of cooling air therethrough in order to provide cooling of the aerofoil portion, the aerofoil portion having a closed tip at an end remote from the platform portion, the closed tip of the aerofoil portion having a cooling passage extending transversely from the leading edge to the trailing edge of the aerofoil portion along the suction surface wall, the cooling passage being formed at least partially by a portion of the suction surface wall extending outwardly from the closed tip, the closed tip having a feed aperture at the leading edge of the aerofoil portion adapted to supply cooling air from the internal passages of the aerofoil portion into the cooling passage, the cooling air supplied to the cooling passage flowing from the leading edge to the trailing edge to provide controlled cooling of the portion of the suction surface wall and the closed tip of the aerofoil, the cooling air being discharged from the cooling passage at the trailing edge of the aerofoil portion.

2. An unshrouded turbine blade as claimed in claim 1 in which the closed tip of the aerofoil portion has a second cooling passage extending transversely from the leading edge towards the trailing edge of the aerofoil portion along the pressure surface wall, the second cooling passage being formed at least partially by a portion of the pressure surface wall extending outwardly from the closed tip, the feed aperture supplying cooling air into the cooling passage and the second cooling passage.

3. An unshrouded turbine blade as claimed in claim 2 in which the portion of the pressure surface wall and the second cooling passage are spaced from the trailing edge of the aerofoil portion.

4. An unshrouded turbine blade as claimed in claim 1 in which the tip of the aerofoil portion is closed by a tip cap, the tip cap forming the cooling passage in cooperation with the portion of the suction surface wall.

5. An unshrouded turbine blade as claimed in claim 4 in which the tip cap has a outwardly extending L-shaped arm which extends from the leading edge to the trailing edge of the aerofoil portion to form the cooling passage.

6. An unshrouded turbine blade as claimed in claim 5 in which the outwardly extending L-shaped arm has a plurality of apertures to discharge cooling air onto the pressure surface of the arm to cool hot spots.

7. An unshrouded turbine blade as claimed in claim 4 in which the tip cap is aerodynamically shaped.

8. An unshrouded turbine blade as claimed in claim 2 or claim 3 in which the tip of the aerofoil portion is closed by a tip cap, the tip cap forming the cooling passage in cooperation with the portion of the suction surface wall and forming the second cooling passage in cooperation with the portion of the pressure surface wall.

9. An unshrouded turbine blade as claimed in claim 8 in which the tip cap has a first outwardly extending L-shaped arm which extends from the leading edge to the trailing edge of the aerofoil portion at the suction side of the tip cap to form the cooling passage, the tip cap has a second outwardly extending L-shaped arm which extends from the leading edge towards but spaced from the trailing edge of the aerofoil portion at the pressure side of the tip cap to form the second cooling passage.

10. An unshrouded turbine blade as claimed in any of claims 1 to 9 in which the internal passages of the aerofoil portion are formed by the pressure and suction side walls and an impingement tube spaced therefrom, the impingement tube supplying cooling air to impinge upon and convectively cool the pressure and suction side walls.

11. An unshrouded turbine blade as claimed in any of claims 1 to 9 in which the internal passages of the aerofoil portion

form a forward flowing multipass cooling system in which the cooling air is supplied to the tip cooling passage or passages.

12. An unshrouded turbine blade suitable for a gas turbine engine substantially as herein described with reference to figures 3 - 8.

Amendments to the claims have been filed as follows

1. An unshrouded turbine blade suitable for use in a gas turbine engine comprising a root portion, a platform portion and an aerofoil portion, the root portion and platform portion having internal passages adapted to supply cooling air into the aerofoil portion, the aerofoil portion having a leading edge and a trailing edge and being defined by a pressure surface wall and a suction surface wall, the aerofoil portion having internal passages adapted for the flow of cooling air therethrough in order to provide cooling of the aerofoil portion, the aerofoil portion having a closed tip at an end remote from the platform portion, the closed tip of the aerofoil portion having a cooling passage extending transversely from the leading edge to the trailing edge of the aerofoil portion along the suction surface wall, the cooling passage being formed at least partially by a portion of the suction surface wall extending outwardly from the closed tip, the cooling passage being closed at a side remote from the closed tip, the closed tip having a feed aperture at the leading edge of the aerofoil portion adapted to supply cooling air from the internal passages of the aerofoil portion into the cooling passage, the cooling air supplied to the cooling passage flowing from the leading edge to the trailing edge to provide controlled cooling of the portion of the suction surface wall and the closed tip of the aerofoil, the cooling air being discharged from the cooling passage at the trailing edge of the aerofoil portion.

2. An unshrouded turbine blade as claimed in claim 1 in which the closed tip of the aerofoil portion has a second cooling passage extending transversely from the leading edge towards the trailing edge of the aerofoil portion along the pressure surface wall, the second cooling passage being formed at least partially by a portion of the pressure surface wall extending outwardly from the closed tip, the second cooling passage being closed at a side remote from the closed tip, the feed aperture

supplying cooling air into the cooling passage and the second cooling passage.

3. An unshrouded turbine blade as claimed in claim 2 in which the portion of the pressure surface wall and the second cooling passage are spaced from the trailing edge of the aerofoil portion.

4. An unshrouded turbine blade as claimed in claim 1 in which the tip of the aerofoil portion is closed by a tip cap, the tip cap forming the cooling passage in cooperation with the portion of the suction surface wall.

5. An unshrouded turbine blade as claimed in claim 4 in which the tip cap has a outwardly extending L-shaped arm which extends from the leading edge to the trailing edge of the aerofoil portion to form the cooling passage.

6. An unshrouded turbine blade as claimed in claim 5 in which the outwardly extending L-shaped arm has a plurality of apertures to discharge cooling air onto the pressure surface of the arm to cool hot spots.

7. An unshrouded turbine blade as claimed in claim 4 in which the tip cap is aerodynamically shaped.

8. An unshrouded turbine blade as claimed in claim 2 or claim 3 in which the tip of the aerofoil portion is closed by a tip cap, the tip cap forming the cooling passage in cooperation with the portion of the suction surface wall and forming the second cooling passage in cooperation with the portion of the pressure surface wall.

9. An unshrouded turbine blade as claimed in claim 8 in which the tip cap has a first outwardly extending L-shaped arm which extends from the leading edge to the trailing edge of the aerofoil portion at the suction side of the tip cap to form the cooling passage, the tip cap has a second outwardly extending L-shaped arm which extends from the leading edge towards but spaced from the trailing edge of the aerofoil portion at the pressure side of the tip cap to form the second cooling passage.

10. An unshrouded turbine blade as claimed in any of claims 1 to 9 in which the internal passages of the aerofoil portion

are formed by the pressure and suction side walls and an impingement tube spaced therefrom, the impingement tube supplying cooling air to impinge upon and convectively cool the pressure and suction side walls.

11. An unshrouded turbine blade as claimed in any of claims 1 to 9 in which the internal passages of the aerofoil portion form a forward flowing multipass cooling system in which the cooling air is supplied to the tip cooling passage or passages.

12. An unshrouded turbine blade suitable for a gas turbine engine substantially as herein described with reference to figures 3 - 8.

PATENTS ACT 1977
EXAMINER'S REPORT TO THE COMPTROLLER UNDER SECTION 17(5)
(The Search Report)

- 15 -

Application No. 8518714

FIELD OF SEARCH: The search has been conducted through the relevant published UK patent specifications and applications, and applications published under the European Patent Convention and the Patent Co-operation Treaty (and such other documents as may be mentioned below) in the following subject-matter areas:-

UK Classification F1V (VCAA)

(Collections other than UK, EP & PCT:) selected US specifications from IPC sub-class F01D

DOCUMENTS IDENTIFIED BY THE EXAMINER (NB In accordance with Section 17(5), the list of documents below may include only those considered by the examiner to be the most relevant of those lying within the field (and extent) of search)

Category	Identity of document and relevant passages	Relevant to claim(s)
X	GB-1357713 (Brown Boveri-Sulzer), see page 2, lines 69-79	1

CATEGORY OF CITED DOCUMENTS

- X relevant if taken alone
- Y relevant if combined with another cited document
- P document published on or after the declared priority date but before the filing date of the present application
- E patent document published on or after, but with priority date earlier than, the filing date of the present application

Search examiner
K E WILLIAMS

Date of search
3 March 1986

SF